be used tentatively in each of the great divisions of the earth, and with reference to the ultimate establishment of a universal scheme after all those divisions have been thoroughly investigated.

The time has come when North American geologists can, and ought to, hold a commanding position in this respect; and when we have elaborated a scheme of classification for the formations of our own continent, it will have equal claim to the favorable consideration of the geological world with any other.

NOTES AND NEWS.

AFTER a stoppage of two years, caused by a lack of funds, work was recently resumed on the double tunnel under the Hudson River between this city and the New Jersey side. Operations are restricted as yet to the Jersey City end of the north or up-river tunnel, which has been excavated to a distance of nearly two thousand feet from the shaft. The total length of the tunnel from shaft to shaft, when completed, will be 5,600 feet, to which must be added the length of the inclines or approaches leading to the surface, work upon which has not been begun. Work is carried on under an air-pressure of about thirty-four pounds to the square inch, and the heading progresses at the rate of twenty-five feet a week.

— Professor Elihu Thompson has perfected an invention by which the rails of street or steam railways may be welded together by electricity after being placed in position. A dynamo propels over the tracks an electric welding machine, which welds the rails into one continuous line after it passes over them. It is proposed to have at every one hundred feet a break, to allow for expansion. Any kind of rails can thus be welded.

— There has been patented in Germany a process by means of which sulphuric acid for manufacturing purposes can be safely transported. The inventor takes advantage of a property of certain salts — of which alkaline sulphates are representatives — by which they give up their water of crystallization when heated and take it up again when cool; and he does so by mixing the salts in an anhydrous condition with a calculated quantity of sulphuric acid. The whole mass becomes granular, or may be formed into cakes, and when heated the whole liquefies, and may be used as if it were sulphuric acid, for the presence of bisulphate of soda does no harm.

— Several reports received at the Hydrographic Office in Washington during the past month serve to illustrate the source of many doubtful or imaginary dangers to navigation that encumber the charts so long before their existence can be disproved. On July 14, in 43° 17′ north latitude, 57° 32′ west longitude, the captain of a Norwegian vessel sighted an immense dead whale which at a distance had the appearance of a rock. A number of sea-birds were about it. On July 22 the German steamship "National," while on a scientific exploring expedition, passed a dead whale under similar circumstances. On Aug. 2 the captain of a British steamship sighted a dead whale, about a hundred feet long, showing six feet out of water. It will readily be seen how easily such an obstruction might be mistaken for a shoal, and, if reported in a region where the depths are not too well known to admit of the possibility of such a thing, it might add one more doubtful danger to the many that have been reported.

— A nailless horseshoe which has been undergoing severe tests in England during the past two years, with satisfactory results, is described as follows: The shoe is attached by a steel band which passes below the coronet from one extremity of the heel to the other. This band is kept in position by a steel pillar which runs from the centre of the shoe up to the centre of the hoof. In addition there are three short studs, one in the centre of the shoe, and the others near the heel and on each side of it. It can be put on by any one who has once seen the process, which takes about half the time required with the cold-shoe system, which latter is an improvement as regards time on the ordinary process with nails. The nailless shoe diminishes or puts an end to cutting, and is particularly suited to brittle hoofs or hoofs with sand cracks. It costs as little, weighs as little, and lasts as long as the ordinary shoe; and, moreover, is not sucked off on heavy ground.

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CONTENTS:

ONE OF THE FEATURES of the meeting of The American Association at Toronto just closed was the growth of the societies devoted to special branches of science which meet each year at the same time and place as the association. The Botanical Club has been in successful operation for some years, as has also the Agricultural Society. This year there was held a meeting of the Geologic Society, and the formation of a chemical society was vigorously discussed. The Entomological Club is another of the groups into which congenial spirits unite, possibly to free themselves of the more cumbersome meetings of the sections of the association. Of the vice-presidents' addresses, we print this week those of vice-presidents R. S. Woodward and C. A. White. That by Professor H. S. Carhart, in the Physics Section, was a review of theories of electrical action. In the Chemical Section, Professor W. L. Dudley spoke of "The Nature of Amalgams." He gave a *résumé* of the most important work done in this interesting field, and a few results of his own. Appended to the address is a complete index to the literature, embracing over three hundred titles. In the Section of Mechanics and Engineering no address was delivered, and the work of the section was quickly over, few papers being presented. Vice-president G. L. Goodale's address before the Biologic Section was on protoplasm. The address of Vice-president Garrick Mallery, before the Anthropologists, treated of the "Israelite and Indian, a Parallel in Planes of Culture." This we hope to print in an early number. The remarks of Vice-president C. S. Hill before the Eco-

nomic Section on the "Economic and Sociologic Relations of the Canadian States and the United States, prospectively considered," roused considerable criticism. The meeting adjourned to meet next year on the third Wednesday in August at Indianapolis. The officers of the meeting will be as follows: president, Professor George L. Goodale, Harvard University; vice-presidents, A, Mathematics and Astronomy, S. C. Chandler, Cambridge, Mass.; B, Physics, Cleveland Abbe, Washington; C, Chemistry, R. B. Warder, Washington; D, Mechanical Science and Engineering, James E. Denton, Hoboken, N. J.; E, Geology and Geography, John C. Branner, Little Rock, Ark.; F, Biology, C. S. Minot, Boston, Mass.; H, Anthropology, Frank Baker, Washington; I, Economic Science and Statistics, J. Richards Dodge, Washington; permanent secretary, F. W. Putnam, Cambridge, Mass., office, Salem, Mass.; general secretary, H. Carrington Bolton, of New York; secretary of the council, James Loudon, Toronto; secretaries of the sections, A, Wooster A. Beman, Ann Arbor, Mich.; B, W. Le Conte Stevens, Brooklyn, N. Y.; C, W. A. Noyes, Terre Haute, Ind.; D, M. E. Cooley, Ann Arbor, Mich.; E, Samuel Calvin, Iowa City, Iowa; E, John M. Coulter, Crawfordsville, Ind.; H, Joseph Jastrow, Madison, Wis.; I, S. Dana Horton, Pomeroy, Ohio; treasurer, William Lilly, of Mauch Chunk, Penn.; auditors, Henry Wheatland, Salem, Mass.; Thomas Meehan, Philadelphia.

THE MATHEMATICAL THEORIES OF THE EARTH.[1]

THE name of this section, which, by your courtesy, it is my duty to address to-day, implies a community of interest among astronomers and mathematicians. This community of interest is not difficult to explain. We can of course imagine a considerable body of astronomical facts quite independent of mathematics. We can also imagine a much larger body of mathematical facts quite independent of and isolated from astronomy. But we never think of astronomy in the large sense without recognizing its dependence on mathematics, and we never think of mathematics as a whole without considering its capital applications in astronomy.

Of all the subjects and objects of common interest to us the earth will easily rank first. The earth furnishes us with a stable foundation for instrumental work and a fixed line of reference, whereby it is possible to make out the orderly arrangement and procession of our solar system and to gain some inkling of other systems which lie within telescopic range. The earth furnishes us with a most attractive store of real problems: its shape, its size, its mass, its precession and nutation, its internal heat, its earthquakes and volcanoes, and its origin and destiny, are to be classed with the leading questions for astronomical and mathematical research. We must of course recognize the claims of our friends the geologists to that indefinable something called the earth's crust, but, considered in its entirety and in its relations to similar bodies of the universe, the earth has long been the special province of astronomers and mathematicians. Since the times of Galileo and Kepler and Copernicus it has supplied a perennial stimulus to observation and investigation, and it promises to tax the resources of the ablest observers and analysts for some centuries to come. The mere mention of the names of Newton, Bradley, d'Alembert, Laplace, Fourier, Gauss, and Bessel calls to mind not only a long list of inventions and discoveries, but the most important parts of mathematical literature. In its dynamical and physical aspects the earth was to them the principal object of research, and the thoroughness and completeness of their contributions toward an explanation of the "system of the world" are still a source of wonder and admiration to all who take the trouble to examine their works.

A detailed discussion of the known properties of the earth and of the hypotheses concerning the unknown properties, is no fit task for a summer afternoon: the intricacies and delicacies of the subject are suitable only for another season and a special audience. But it has seemed that a somewhat popular review of the state of our mathematical knowledge of the earth might not be without interest to those already familiar with the complex details, and might also help to increase that general interest in science, the promotion of which is one of the most important functions of this association.

As we look back through the light of modern analysis, it seems strange that the successors of Newton, who took up the problem of the shape of the earth, should have divided into hostile camps over the question whether our planet is elongated or flattened at the poles. They agreed in the opinion that the earth is a spheroid, but they debated, investigated, and observed for nearly half a century before deciding that the spheroid is oblate rather than oblong. This was a critical question, and its decision marks perhaps the most important epoch in the history of the figure of the earth. The Newtonian view of the oblate form found its ablest supporters in Huyghens, Maupertuis, and Clairaut, while the erroneous view was maintained with great vigor by the justly distinguished Cassinian school of astronomers. Unfortunately for the Cassinians, defective measures of a meridional arc in France gave color to the false theory and furnished one of the most conspicuous instances of the deterring effect of an incorrect observation. As you well know, the point was definitely settled by Maupertuis's measurement of the Lapland arc. For this achievement his name has become famous in literature as well as in science, for his friend Voltaire congratulated him on having "flattened the poles and the Cassinis," and Carlyle has honored him with the title of "Earth-flattener."

Since the settlement of the question of the form, progress towards a knowledge of the size of the earth has been consistent and steady, until now it may be said that there are few objects with which we have to deal whose dimensions are so well known as the dimensions of the earth. But this is a popular statement, and like most such, needs to be explained in order not to be misunderstood. Both the size and shape of the earth are defined by the lengths of its equatorial and polar axes; and, knowing the fact of the oblate spheroidal form, the lengths of the axes may be found within narrow limits from simple measurements conducted on the surface, quite independently of any knowledge of the interior constitution of the earth. It is evident in fact, without recourse to mathematical details, that the length of any arc, as a degree of latitude or longitude, on the earth's surface, must depend on the lengths of those axes. Conversely, it is plain that the measurement of such an arc on the surface and the determination of its geographical position, constitute an indirect measurement of the axes. Hence it has happened that scientific as distinguished from practical geodesy has been concerned chiefly with such linear and astronomical measurements, and the zeal with which this work has been pursued is attested by triangulations on every continent.

Passing over the earlier determinations as of historical interest only, all of the really trustworthy approximations to the lengths of the axes have been made within the half century just passed. The first to appear of these approximations were the well-founded values of Airy, published in 1830. These, however, were almost wholly overshadowed and supplanted eleven years later by the values of Bessel, whose spheroid came to occupy a most conspicuous place in geodesy for more than a quarter of a century. Knowing as we now do that Bessel's values were considerably in error, it seems not a little remarkable that they should have been so long accepted without serious question. One obvious reason is found in the fact that a considerable lapse of time was essential for the accumulation of new data, but two other possible reasons of a different character are worthy of notice, because they are interesting and instructive whether specially applied to this particular case or not. It seems not improbable that the close agreement of the values of Airy and Bessel, computed independently and by different methods, — the greatest discrepancy being about one hundred and fifty feet, — may have been incautiously interpreted as a confirmation of Bessel's dimensions, and hence led to their too ready adoption. It seems also not improbable that the weight of Bessel's great name may have been too closely associated in the minds of his followers with the weight of his observations and results. The sanction of eminent authority, especially if there is added to it the stamp of an official seal, is sometimes a serious obstacle to real progress. We cannot do less than accord to Bessel the first place among the

[1] Address before the Section of Mathematics and Astronomy of the American Association for the Advancement of Science, at Toronto, Ont., Aug. 28–Sept. 3, by R. S. Woodward, vice-president of the section.